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CC: Keenan

Golder Associates

TRANSMITTAL

Date: 04/05/2016

To: Mr. Keenan Storrar

From: Jeff Clark

cc:

Email: jclark@golder.com

RE: **DEER CREEK MINE**

Project No.: 1547013

Company: Utah Division of Oil, Gas, and Mining

Address: 1594 W North Temple
Suite 1210
Salt Lake City, UT 84116

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1	Review of Mine Installation Plan	Report dated 4/1/2016

Notes:
Please call me if you have any questions or concerns at 505-821-3043.

Thank you,

Jeff Clark

Please advise us if enclosures are not as described.

ACKNOWLEDGEMENT REQUIRED:

- [ ] Yes
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REPORT

REVIEW OF MINE PLUG INSTALLATION PLAN

Deer Creek Mine

Submitted To: Mr. Keenan Storrar
Utah Division of Oil, Gas and Mining
1594 W North Temple, Suite 1210
Salt Lake City, UT 84116

Submitted By: Golder Associates Inc.
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1.0 INTRODUCTION

Golder Associates Inc. (Golder) has prepared this review report for the Utah Division of Oil, Gas and Mining (Division) to assist the Division with review of the proposed mine plug construction plan at the Deer Creek Mine (the Mine). The Mine is an underground coal mine near Huntington, Utah owned by Interwest Mining Company, a wholly owned subsidiary of Pacificorp (the Owner). The closure plan, prepared by the Owner, includes using bulkheads to elevate the mine water pool above an in-mine drainage divide and provide gravity drainage to the Deer Creek Portals. The Division will approve or deny the closure plan based on the short term (approximately ten years) and long term (in perpetuity) effectiveness for protecting public health and the environment.

Golder's review was generally focused on the bulkhead design, with regards to short and long term effectiveness. This included evaluating: the applicable factors of safety, mine volume estimates, that deficiencies previously identified by the Mine Safety and Health Administration (MSHA) reviewers have been addressed (MSHA 2015), the potential for plugging of the French drain or drain pipe, appropriateness of the specified materials, the effectiveness of the post-closure monitoring systems.

This review is limited by the information available. In preparing this review, Golder has reviewed the following documents:

- *Amendment to Volume 12, Chapter 7, Hydrology, Deer Creek Mine, C/015/0018, Emery County Utah,*' Pacificorp, 2015) (Amendment).
- Final Closure Plan Proposed Interlocking Parallel Plugs with Gravity Drainage, Interwest Mining Company, December 2015 (Appendix D of the Amendment) (Final Closure Plan).
- Deer Creek Mine Final Closure Project, Request for Proposal for Interlocking Parallel Plugs "Bulkheads", for PacifiCorp/Interwest Mining (Owner), East Mountain Energy, LLC (Operator) (RFP).
- Calculations provided by the Owner.
- Letter from MSHA dated Sept. 8, 2015, RE: Deer Creek Mine, ID No. 42-00121, Site-specific Ventilation Plan: Bulkheads and Portal Seals ("Disapproval Letter").
- Memorandum (attached to the Disapproval Letter) from MSHA dated August 21, 2015 RE: Evaluation of Revised Plans to Construct Two Sets of Bulkheads and One Set of Portal Plugs at the Deer Creek Mine, Mine I.D. No. 42-00121, Interwest Mining Company, Huntington, Utah.

This review focused on the Final Closure Plan. Additionally, the RFP contains specifications and details not included in the Amendment or Final Closure Plan. A review of the technical specifications in the RFP, indicates that the Owner has already addressed several items that Golder identified as concerns in the Final Closure Plan (e.g., concrete specifications). No mine models or hydrogeologic models were provided by the Owner.

1.1 Definitions

Bulkheads and/or plugs in openings to surface are typically designed as part of mine closure for one of two purposes:

- Where the opening is anticipated to be below the equilibrated water table following mine closure, to reduce or control the flow of water out of the heading; and
- Where the opening is above the static water table, to reduce the influx of air (and thus oxygen) into the mine workings, such that the oxidation of exposed wall rocks, and thus leaching of metals, is limited.

For the purposes of this report, a bulkhead is defined a temporary (i.e., life of mine only) structure which impounds moderate hydraulic heads (e.g., ranging between 15 to 150 pounds per square inch [psi]), while a plug is considered to be permanent closure structure used to impound water (or tailings) at pressures exceeding approximately 15 psi.

Where the opening need only be closed to reduce the influx of air, the design for such structures needs to consider ease of construction, management of long term access and, in the special case of vent shafts, the collapse of shaft sidewalls and potential development of surface subsidence. As these structures do not pond water, in the context of this report, they are considered to be bulkheads. Their design does not consider any loading of their face, except due to air pressure.

By comparison, the potential failure mechanisms that must be considered for permanent plugs retaining water include: punching shear, deep beam flexure (or bending moment), potential to resist hydraulic fracture, hydraulic gradient and long term degradation (e.g., via chemical attack). Suggested factors of safety and other considerations for each failure mode are summarized in Table 1. The selected length for each plug will be the one which corresponds to the most critical of these conditions.

Table 1 – Summary of Plug Design Criteria (after Lang, 1999)

Failure Mode	Design Criteria
Punching shear failure along rock/concrete contact or through rock mass	F.S. > 3 normal condition F.S. > 1.5 earthquake or dynamic load condition
Deep beam flexure (i.e., bending moment)	F.S. > 3 normal condition F.S. > 1.5 earthquake or dynamic load condition
Hydraulic jacking of rock surrounding plug	F.S. > 1.3 normal condition (total stress analysis) F.S. > 1.1 earthquake or dynamic load condition (total stress analysis)
Excessive seepage around plug and possible downstream erosion	Maximum hydraulic gradient based on empirical design methods.
Long term disintegration of concrete	Concrete to be designed to appropriate standards for resistance to acid attack, sulfate attack, and alkali aggregate reactivity. Sensitivity of other construction materials to be determined on a case-by-case basis.

The design guidelines for a parallel-sided plug (also referred to as an "unhitched") design can be found in publications such as the Bureau of Mines Information Circular 9020, "*Design of Bulkheads for Controlling Water in Underground Mines*" (Chekan, 1985). The main parameter for plugs of this type is the length of concrete that must be cast in the drift to ensure a stable structure.

2.0 CLOSURE PLAN REVIEW

Golder's understanding of the closure plan is based on review of the Amendment including the Final Closure Plan, and discussion with Division and Owner personnel. The closure plan includes construction of three sets of interlocking parallel plugs: two primary plugs (1st Right XC-4 and 6th North XC-9), a secondary plug (1st Right XC-37 and XC-38), seal enhancements in 5th North, and portal seals in Rilda Canyon Portals. The two primary plugs are intended to direct drainage to the Deer Creek Portals through either a French drain and directional drill hole immediately inby the 1st Right primary plug (the primary spillway), or through the slope connecting the Blind Canyon and Hiawatha Seams (secondary spillway). In the event that the drain pipe (primary spillway) becomes blocked, the water level will rise to the upper workings (Blind Canyon seam) where the 5th North Seal Enhancements will serve to direct the water away from the Rilda Canyon workings. The secondary plug is intended to provide redundancy for and retain leakage from the primary plugs, and direct leakage and 'nuisance' water (water entering the workings outby the primary plugs) into the Hiawatha seam of the Rilda Canyon workings. The portal seals are portal closures, are not anticipated or intended to retain water, and therefore are not designed as hydraulic bulkheads and are not included in this review.

As further discussed in following sections, in the long term, we consider it likely that the primary spillway will become fouled or blocked and cease to provide the flow required to prevent ponding to the secondary spillway. Therefore, our review of the plug design focuses on the full potential hydraulic loading presented by the elevation of the secondary spillway. With the primary drainage functioning: the 1st Right primary plug will be subjected to a hydraulic head of approximately 7 feet of water, or 3 psi, the 6th North plug would be subjected to between 0 and 2 feet of water head (up to 1 psi), and 5th North seals would not be subjected to water pressure. With the mine pool to the secondary spill location: the primary plugs would be subjected to a maximum of approximately 127 feet of water head (55 psi), and the 5th North seals to approximately 9 to 14 feet of water head (4 to 6 psi).

The secondary plugs should not be subjected to significant hydraulic loading; if the primary plugs remain functional, the secondary plug will direct bypass and nuisance water into the Rilda Canyon workings. The elevation difference between the primary and secondary plugs is approximately 140 feet, a potential water head of 60 psi. If the primary plugs were to fail, the secondary plug could be subjected to the full hydraulic head of 250 feet (to the elevation of the secondary spillway). Concerns regarding the secondary plug are detailed in following sections.

2.1 MSHA Concerns

A previous iteration of the closure plan was provided to the MSHA for review. In the "Disapproval Letter" and accompanying memorandum (MSHA, September, 2015), MSHA identified several concerns and did not approve the bulkhead plan. The Owner subsequently revised the closure plan such that many of the concerns in the letter and memorandum are no longer applicable. MSHA review comments (in italics) and the applicability are summarized below.

Cementitious foam bulkheads do not have an established performance history of resisting high heads, and the shear strength of the material may not be adequate.

> The comment is no longer applicable. The design has been changed to use self-consolidating concrete rather than cementitious foam.

It is anticipated that the coal-measure strata and seam will not be able to hold the water head, and failure could occur through the rock mass even with grouting.

> The Owner has addressed this comment through the change in design: the total water head has been significantly reduced, and plug lengths have been significantly increased. As further discussed in following sections, this concern remains applicable for the secondary plug location.

In the recent water immersion tests of the strata cores, there was no rubbing or agitation of the samples to show that they were not weakened. Tests did not include the mudstone floor at 1st right.

> Slake durability test results are not included in the Amendment; however, immersion tests showed essentially no degradation. In the closure condition, strata will not be subjected to rubbing or agitation, and as such the slake durability test would present a conservative testing approach. Mine personnel indicate that the rock strata is generally not reactive and has not been observed to degrade when exposed to air or water. The Amendment states that the weak mudstone in the floor at 1st Right is to be excavated to competent rock prior to plug construction; however, the mudstone will remain in contact with the plug in the ribs. This comment may originate from the National Institutes of Occupational Safety and Health (NIOSH) bulkhead design guidance (Harteis, S.P, D.R. Dolinar, and T.M Taylor, 2008) which includes utilizing the slake durability test. The NIOSH guidance recommends that plugs be located in rock with a minimum of medium-high slake durability and non- to slightly sensitive rock based on the immersion test.

Polyurethane grout has a limited lifespan of 75 to 100 years.

> As revised, microfine cement is substituted for polyurethane grout. Grouting is further discussed in following sections.

There was no evaluation of hydraulic fracture or internal erosion (piping) potential.

> Factors of safety are evaluated in following sections. The plug length has been significantly increased to address the piping potential, and the potential water head has been significantly

reduced to address the hydraulic fracture potential. As further discussed in following sections, hydraulic fracture is a concern for the secondary plug location.

Calculated factor of safety was overstated for the concrete portal plugs. There was no evaluation of hydraulic fracture or piping potential.

As revised, portal plugs will not be subjected to hydraulic loading.

For the concrete portal plugs, the design did not include: contact and strata grouting, tapered hitches, measure to control heat of hydration cracking and provide for chemical durability, and a pressure gauge. The depth of burn was not considered in the barrier calculations.

The portal plugs have been relocated, and as designed, will not be subjected to hydraulic loading. Design elements and monitoring of the primary and secondary plugs are further discussed in following sections.

2.2 Parallel Plugs and Seal Caps

Observations of the 1st Right Primary and 6th North Parallel Plugs and 5th North Seal Enhancement (or cap) were carried out during a site tour provided by the Owner on March 1, 2016. Grant Bonin and Jeff Clark of Golder and Keenan Storrar of the Division were escorted by mine personnel Chuck Semborski, Ken Fleck, and Louie Tonc. The proposed plug and seal cap locations, provided they are scaled, washed and cleaned to fresh, competent bedrock along the full lengths of each plug, were observed to be adequate.

During the site inspection, it was noted that fresh coal exposed in the plug sidewalls are generally strong and of fair rock mass quality, while sandstone in the roof and floor of the proposed plug locations was of strong to very strong, widely jointed, good rock mass quality. However, near the floor, in the sidewalls of the inspected plug locations in the 6th North, a layer of friable, weak, closely fractured, poor to very poor quality siltstone was present. Golder has utilized these rock mass qualities for the assessment of the plug length, providing a more conservative approach (and lower factor of safety) than was presented in the Amendment.

The potential hydraulic heads acting on each plug location and proposed plug lengths were obtained from Appendix G of the Final Closure Plan; heads are consistent with the elevations provided by the Amendment. The heading dimensions (width and height) in which each plug will be constructed were obtained from Figures 7A through 7D in the Final Closure Plan, while the minimum overburden cover thicknesses were extrapolated from Figures 3A through 3D. The factors of safety against failure at each plug location with respect to punching shear, deep beam flexure, potential to resist hydraulic jacking and hydraulic gradient are summarized below in Table 2.

These factors of safety only consider the heads for the secondary spillway, at the top of the 4th North Slope, or 8,010 feet elevation. The secondary spillway heads are assumed to represent the worst case, and likely represent the long term scenario (i.e., the directionally drilled water drain or French drain becomes plugged over time). In the case that the primary spillway is functional, the heads are significantly lower, increasing the factor of safety for punching shear, hydraulic jacking and hydraulic gradient (deep beam failure is dependent upon the plug dimensions hydraulic load).

In calculating factors of safety against the potential increased load provided by seismic activity, Plate 1 downloaded from the 2008 U.S. Geological Survey (USGS) National Seismic Hazard Maps collection for Utah (USGS, 2014), shows that the estimated peak ground acceleration (PGA) with a return period of 4,975 years (i.e., at a probability of 2% over 50 years) is approximately 0.27 g – yielding a short-duration, additional water hammer load (per Lang, 1999) on the plugs of approximately 30 psi.

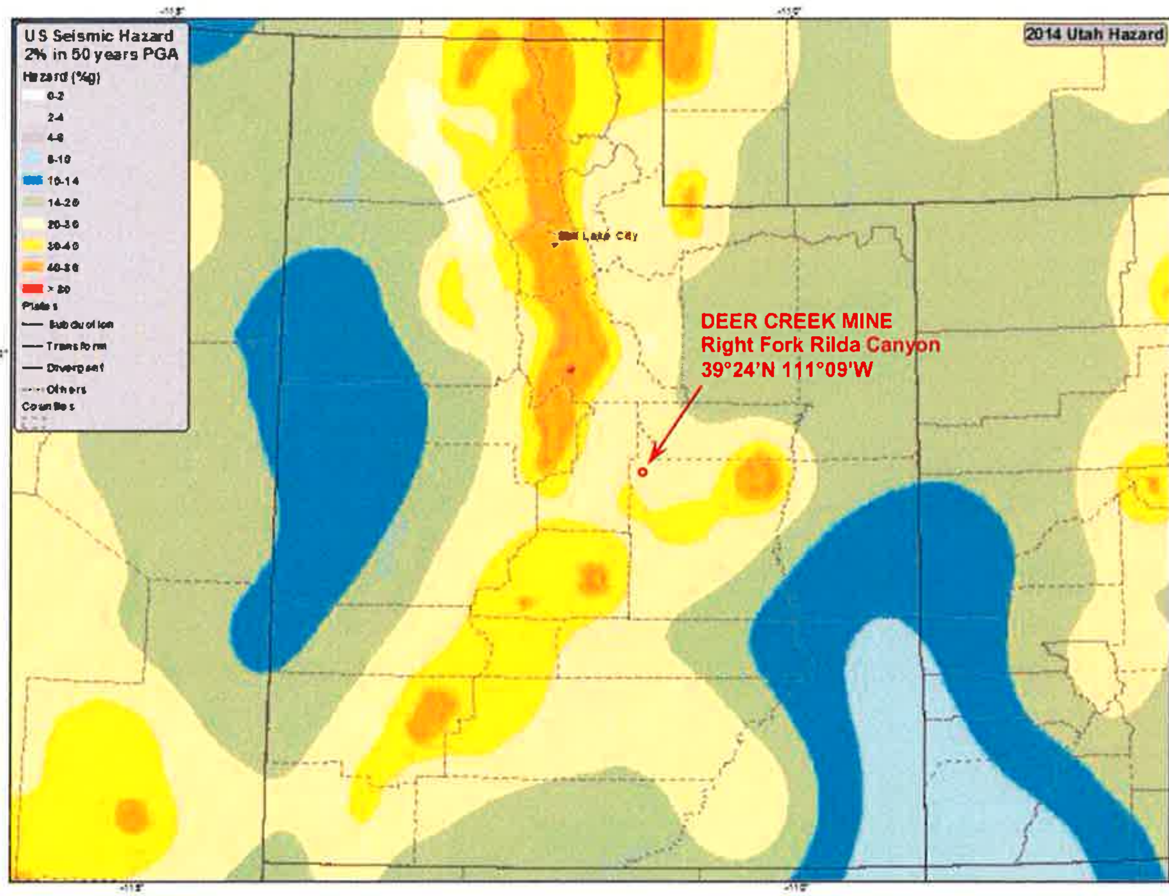

Plate 1: 2014 National Seismic Hazard Map for Utah

To illustrate the acceptability of the proposed plug lengths, it was also assumed that:

- The cured plug concrete strength would be 4,000 psi;
- An allowable shear strength of 7.3 psi (after Benson, 1989) for a very weak, possibly erodible rock mass would be available to resist punching shear; and
- As pertains to hydraulic gradient, a maximum allowable hydraulic gradient along an ungrouted plug contact of 2.1 psi/foot plug length with a factor of safety of 10 for a weak, possibly erodible rock mass (per Garrett and Campbell Pitt, 1961) was applicable.

Table 2 – Summary of Plug Design Factors of Safety

Plug Location		Design Water Head Static/ Seismic (Feet)	Calculated Static (Seismic) Load Factors of Safety			
Heading	Entry		Punching Shear	Deep Beam	Hydraulic Jacking	Hydraulic Gradient
1st Right XC-4	-1	122 (190.5)	14.4 (9.2)	27.1 (21.7)	7.4 (4.8)	3.9
	0	121 (189.5)	12.8 (8.2)	35.9 (28.7)	6.9 (4.4)	4.7
	1	121 (189.5)	14,6 (9.3)	36.9 (29.5)	6.9 (4.4)	4.9
	2	120.5 (189)	15.7 (10)	24 (19.2)	6.3 (4.0)	4
	3	121 (189.5)	14.9 (9.5)	27.6 (9.5)	5.6 (3.6)	4
6th North XC-9	1	111.5 (180)	8.2 (5.1)	14.6 (11.5)	9.4 (5.8)	2.1
	2	112 (180.5)	8 (4.9)	14.9 (11.7)	11.6 (7.2)	2.1
	3	113 (181.5)	7.2 (4.5)	15.2 (12)	8.9 (5.6)	2.1
	4	115 (183.5)	7 (4.4)	14.9 (11.8)	7.8 (4.9)	2.1
	5	119 (187.5)	7.1 (4.5)	14.3 (11.4)	8.3 (5.3)	2
1st Right Secondary	1	250 (318.5)	5 (3.9)	14.8 (13.1)	1.7 (1.4)	1.4
	2	248 (316.5)	4.9 (3.9)	14.7 (13)	1.4 (1.1)	1.4
	3	247 (315.5)	6.8 (5.3)	21.3 (18.8)	1.1 (0.9)	2
	4	247 (315.5)	4.7 (3.7)	15.2 (13.5)	0.7 (0.6)	1.5
5th North XC-11	1	11.0 (--)	17.2 (--)	10.6 (--)	62.5 (--)	5.2
	2	10.0 (--)	18.4 (--)	10.7 (--)	65.2 (--)	5.7
	3	11.0 (--)	17.3 (--)	10.6 (--)	71.4 (--)	5.2
	4	13.3 (--)	14.8 (--)	9.8 (--)	63.4 (--)	4.3
	5	12.7 (--)	15.4 (--)	10.1 (--)	63.8 (--)	4.5
	6	12.4 (--)	17.5 (--)	10.3 (--)	62.6 (--)	4.6

Notes:

1. For the 5th North XC-11 Seals, as these seals will not pond water the full height of the plug face, water hammer effects are not anticipated to occur.
2. The factors of safety with respect to the hydraulic gradient criteria are those calculated for an ungrouted contact. The plug concrete-to-bedrock interface of the 1st Right and 6th North Primary Plugs will be grouted. As such, the factors of safety with respect to the hydraulic gradient criteria will be seven- to eightfold higher.

With the exception of the 1st Right XC-37 and 38 Secondary Parallel Plugs, the proposed plug lengths are acceptable with respect to punching shear, deep beam flexure and potential to resist hydraulic jacking. As the plug concrete-to-bedrock interface will be pressure grouted, the proposed plug lengths are also acceptable from a hydraulic gradient perspective.

Samples of groundwater collected by the Owner in May 2012 from the Blind Canyon 10th North XC-5 Borehole contain levels of sulfate (SO_4) ranging between 180 and 230 parts per million (ppm). While mixing of ponded waters is anticipated to reduce sulfate concentrations, as groundwater samples obtained from the Hiawatha 17th West and 11th West Sumps (i.e., progressively closer to the proposed 1st Right XC-4 and 6th North XC-9 primary plugs) contain <150 ppm and <45 ppm sulfate, respectively, we suggest that moderate sulfate resistant (Type II) or general purpose (Type I) cement with greater than 35% Type F fly ash replacement be used for plug construction purposes. Provided contact grouting is carried out, it has also been our experience that a sacrificial length of three feet is more than sufficient to protect the core of the plug from long-term degradation. Given the lengths of the proposed primary plugs, sufficient sacrificial length exists such that punching shear, deep beam flexure and hydraulic gradient (i.e., design criteria which require a given plug length to resist failure by that criteria) are still satisfied.

If the directionally drilled drain were to become plugged, the mine waters to pond and overtop the Secondary Spillway, and the 1st Right XC-4 Primary Plugs were to leak such that the 1st Right XC-37 and XC-38 Secondary Plugs were to pond the full head of water (i.e., to the top of the 4th North Slope, approx. 250 feet of water head), sufficient overburden cover to resist the potential for ponded water to hydraulically jack open existing discontinuities at the location of the 1st Right XC-37 Secondary Plugs in Entries 3 and 4 does not exist. Using the Norwegian Cover Criteria for unlined pressure tunnels, (Dahlø, T.S., Bergh-Christensen, J. and Broch, E., 1992), a maximum of 100 feet head of water could safely be ponded by the Entry 3 and 4 secondary plugs. The assumed minimum stress conditions could be confirmed by carrying out hydraulic jacking tests prior to plug construction.

2.3 Construction Considerations

The technical specifications within the RFP (East Mountain Energy, 2016) and other construction considerations provided in the Amendment were reviewed. In general, comments below apply to all plug locations. Where possible, we have cross-referenced by clause within the technical specifications. For the purpose of this review, we have considered the specifications supplemental to and/or to supersede the Amendment.

Site Preparation:

- At each plug location, per Clause 2.01.3, we agree that all loose materials and wood should be removed from the roof, floor and ribs, and that roof and ribs should be scaled "to a competent member"; the roof, floor and ribs washed; and any standing water removed.

Additionally, the Owner should specify that competence will be defined as fresh coal in the ribs and/or sandstone in the floor and roof. In the lower ribs of the 6th North plug location, where friable siltstones are present, we also agree that if such materials are present in the floor of the plug, they should be excavated to expose the underlying sandstone (or a "competent lithologic member") in the plug floor.

- We recognize that from a safety perspective, during site preparation, it may not always be possible to remove the roof mesh attached to the back. While not anticipated, to confirm that no gap has been left between the mesh and roof during concreting, we agree that per Clause 6.06.2, that it will be necessary to carry out contact grouting of the plug concrete-to-bedrock interface.
- We consider preparation of the plug location to be critical in construction of a closure plug. Every possible effort should be made to achieve a clean rock surface throughout the plug extents.
- Consider installing trash screens upstream of the primary plug to prevent floating materials from reaching the French drain system and monitoring holes. Materials should be selected for long term durability in the mine environment (e.g., geosynthetic mesh, fiberglass roof bolts).
- Consider installing additional ground support immediately upstream and downstream of the plug locations. Maintaining a stable roof will help reduce development of seepage pathways (Harteis, S.P, D.R. Dolinar, and T.M Taylor, 2008). Materials should be selected for long term durability in the mine environment.

Concreting:

- As described in Clause 6.02, the plugs will be poured using a self-consolidating concrete (SCC) mix. The size of the plugs result in massive monolithic concrete pours. As such, there is potential for development of a considerable thermal gradient between the core of the plug and the faces. To reduce this potential, consideration should be given to:
  - In Clause 6.02.2.2, the use of a high fly-ash replacement (>55%) mix design to reduce the heat of hydration;
  - A 56-day (rather than 21-day, per Clause 6.02.2.1) unconfined compressive strength of 4000 psi;
  - The use of a layer of polystyrene foam insulation sheathing on the interior of the formwalls; insulation can be left in place when forms are stripped.
  - Not stripping the formwalls of the upstream and downstream faces until the core temperature of the plug has cooled to within 20°F of the surrounding original rock mass temperature.
  - The embedment, and grouting in of single-node thermistors into the host rock mass, and suspended (tied-down) throughout the plugs to monitor plug curing temperatures and thermal gradients.
- As the SCC will most likely be batched on surface and pumped to the various plug locations, the use of ⅜-inch minus coarse aggregate is suggested (Clause 6.02.2.5).
- Specify an ASTM 6012 slump flow of between 24 and 28, in addition to the Visual Stability Index value of 1 or less (per Clause 6.02.2.9).
- Specify minimum testing requirements (e.g., slump flow and cylinder collection frequency) throughout the pour dependent upon the placement and mixing methodology.

Grouting:

- A continuous high-strength contact along the plug concrete-rock interface is of utmost importance in developing the full shear strength evenly over the plug surface and in resisting any flow of water. Although the concrete will be cast against the excavated rock, shrinkage during setting of the concrete may result in voids, especially in the roof where incomplete filling may have occurred; contact grouting should be required after curing is completed (Clause 6.06.2).

  Garrett and Campbell-Pitt (1961) describe in detail, a number of leakage tests carried out on monolithic concrete plugs. In particular, they note that the un-grouted plug concrete-to-bedrock interface during their water up tests leaked so heavily that it was impossible to pond more than 75 psi of water pressure. While it is recognized that in the worst case scenario, neither the 1st Right Primary nor 6th North Plugs will pond more than 55 psi, nevertheless, 55 psi is two-thirds of the noted maximum un-grouted contact pressure, and as such, significant leakage would be anticipated in the worst case scenario.

- Contact grouting should not be allowed to commence until the core temperature of the plug has cured to within 10°F (rather than 50°F, per Clause 6.06.1) of the background temperature to allow the concrete to have shrunk completely. Over the proposed length of the plugs, the specification of a non-shrink concrete mix design is not a guarantee that the possibility of shrinkage, even a very small amount, does not exist. Ultrafine cement with a D95 of <10 microns will permeate shrinkage separations of >50 microns (or 0.002-inches).
- Contact grouting need only be carried out to twice the maximum design head, or approximately 110 psi (rather than 300 psi, as per Clause 6.06.2).
- As shown on Figure 11 of the Final Closure Plan, we agree that the consolidation grouting should be carried out at the same end from which contact grouting will be carried out post-construction.
- It is not possible to quantify the seepage rates with the information provided in either the grouted or un-grouted condition; however, the seepage rate should be expected to increase as the head increases (i.e., seepage will be greater under the secondary spillway condition than under the primary spillway condition). Hydrogeologic modeling could be completed to estimate the seepage rates around the plug and through the rock mass (e.g., to surface at the outcrop in Rilda Canyon).
- As noted on Page 27 in Appendix D of the Final Closure Plan, consolidation grouting will be carried out mid-pillar, prior to plug construction using microfine neat cement grouts. Microfine cements are considered to be those with a D95 ranging between 10 and 30 microns, while ultrafine cement are those cement grinds with a D95 of <10 microns. Given the reported low permeability of the sandstone, siltstone and coal at the Deer Creek Mine, it is suggested that consolidation grouting be carried out with an ultrafine neat cement grout.

5th North Seal Enhancement:

- The 5th North Seal Enhancements are understood to only be subjected to low heads and are intended to simply deflect water down the Secondary Spillway.
- Assuming the plug locations are prepared as specified, we have not identified any concerns with the Seal Enhancement construction.

2.4 Secondary Plugs and Rilda Canyon Workings

The 1st Right Secondary Plugs are understood to provide redundancy, and serve to direct any water entering the workings outby the primary plug (both seepage around the plugs and nuisance water) into the North Rilda Canyon workings. Failure of the 1st Right Primary Plugs could result in a hydraulic head of approximately 250 feet of water head (for the secondary spillway, 105 psi) on the secondary plug. Assuming full connectivity through the isolation seals, the North Rilda Canyon workings and barrier pillars would also be subjected to this pressure.

As discussed in Section 2.2, at the full potential head, insufficient ground cover (i.e., shortest distance between the upstream roof and the ground surface, perpendicular to the topography) exists to prevent the potential opening of existing discontinuities by hydraulic jacking. Additionally, the southeastern extent of the North Rilda Canyon Hiawatha workings appears to be have the thinnest ground cover. The southeastern extent of the North Rilda Canyon Hiawatha workings is down dip from the secondary plug. The floor elevation in this area presents an elevation difference of approximately 380 feet from the elevation of the secondary spillway resulting in a potential hydraulic head of 165 psi. While surface topography for this area is not provided in the Amendment, cover over the southeastern extent of the North Rilda Canyon workings is estimated at approximately 100 feet thick; ground surface elevations in this area appear to be significantly lower than the maximum ponding elevation in the mine. The overburden in this area is also likely to have been affected by subsidence of the adjacent longwall panel (i.e., opening fractures).

In addition to insufficient ground cover for the potential head, the barrier pillar in the southeastern extent of the North Rilda Canyon Hiawatha may be insufficient to prevent significant seepage. The barrier pillar in this area appears to be approximately 200 feet thick; however, this is understood to include an unknown, but significant thickness of rock/coal damaged by burns. While understood to be conservative, the Ash and Eaton Impoundment Formula indicates a barrier pillar width of 212 feet thick would be required for the potential head (Kendorski, F.S., and M.D. Bunnel, 2007). This barrier pillar thickness is significantly greater than that found using other methods (e.g., the Pennsylvania Mine Inspector's Formula results in a thickness of approximately 100 feet), but a conservative approach is appropriate given the long term nature of the system.

While seepage modeling has not been completed, if flooded and subjected to the maximum possible pressure (approximately 165 psi), it is possible that springs would develop in North Rilda Canyon. Seepage to the ground surface increases the potential for instability of the soil and rock slopes. Slope failure could further reduce the cover thickness, increasing seepage and potentially resulting in catastrophic release of water. We understand that seep monitoring is planned in North Rilda Canyon should pressures exceed 15 psi on the secondary plug; however, a hydrogeologic model could be developed to further evaluate this risk.

2.5 Monitoring

Proposed plug monitoring consists of installing a pressure transducer through a borehole to the surface in 1st Right at XC-3.5. A second borehole has been drilled at this location to serve as a backup and allow for air and water quality monitoring. Two boreholes are also located in 1st Right at XC-28 (between the primary and secondary parallel plugs) that can be utilized for future monitoring.

In general, given the intent that the plugs serve as long term closure structures, the Owner and Division should consider additional monitoring systems. We recommend maintaining access to the outby side of the plug for regular visual observation and maintenance (e.g., grouting). In addition to monitoring the leakage rate and head pressure on the plug, the NIOSH guidance document (Harteis, S.P, D.R. Dolinar, and T.M Taylor, 2008) recommends conducting "routine examinations of the bulkheads and surrounding strata", including monitoring for signs of "increased stress or deterioration of the bulkhead material... piping...leakage and changes in the condition of the strata".

We understand that maintaining safe long term access will be difficult and is not intended, and that installation of additional remote monitoring will be simplified while access is still available. The Owner and Division should consider including additional remote monitoring, such as:

- Using weirs with pressure transducers, to remotely monitor flow rates both upstream and downstream of primary and secondary plug locations
- Using pressure transducers inby the primary and secondary plugs at various locations to monitor for differential pressures
- Monitoring the pressure inby the Rilda Canyon Seals (using piezometers or transducers) to monitor filling of the North Rilda Canyon workings and pressure on the Rilda Canyon outcrop

In addition, the Owner and Division should consider monitoring in the Crandall Canyon Mine. NIOSH guidance (Harteis, S.P, D.R. Dolinar, and T.M Taylor, 2008) recommends identifying "all mine works, both active and inactive, that could impact the amount of fluid flowing into and out of the proposed underground impoundment". The northern extent of the Mill Fork Workings will be 'dead storage', possibly resulting in seepage to the Crandall Canyon mine; however, due to the thickness of the barrier pillar (approximately 500 feet), low head in this area, and low conductivity of the strata, we consider significant flow to Crandall Canyon workings unlikely. A hydrogeologic model could be used to predict the seepage across the barrier pillar.

2.6 Geochemistry

Our geochemistry review focused on the presence of iron in the Mill Fork area mine water and its potential influence on the French drain and directional drill hole drainage system (the primary spillway). The following comments summarize the findings of our review:

Source of iron:

- We understand that the primary source of iron in the Mill Fork area is the oxidation of iron sulfide minerals present in the Hiawatha seam. These minerals are exposed on the mine walls, roof, and floor and are oxidized in the presence of air and standing water, infiltrating groundwater, or condensation.
- The estimated depth of potentially reactive materials is unclear; an assumption of two feet is presented in the Amendment, but the calculation attached as Appendix A, Table 2 uses a depth of one foot. If the reactive sulfur mass was underestimated then it is likely that the potentially available mass of both iron and sulfur, as well as the time period for their release is greater than reported. Further, the mass of sulfide minerals available for oxidation in Appendix A, Table 2 appears to be underestimated. The calculated mineral masses of iron sulfide, pyrite and marcasite relate to only the mass of sulfur in these minerals.
- Beltlines and ground support remaining in the mine after closure represent a secondary source of iron to mine waters. These materials will corrode over time depending on the availability of oxygen and water (e.g., dew from humidity, or groundwater inflows that contact the equipment). We agree that it is difficult to estimate the amount of iron available and predict the rate of iron release because the post-closure mine environment will be different than during operations.

Iron mobility:

- Mine water monitoring results from the Hiawatha 11th West and 17th West seals show total iron concentrations ranged from 0.44 to 9.79 mg/L, but typically no dissolved iron was detected (<0.03 mg/L). This implies that most iron occurs in colloidal/suspended form. Although gas monitoring results from inside the seals are consistent with an atmosphere sealed off from the rest of the mine, the abundance of suspended solid iron suggests sufficient oxygen remains in the collapsed longwall panels for iron oxidation and precipitation to occur at an early stage in the flow path close to the sulfide mineral source. Additionally, Bucket testing of 17th West seal water conducted by Mayo (2015) showed iron precipitation occurred over time with oxygen entrainment. This suggests some dissolved iron may have been present, but oxidized and precipitated rapidly.
- It is possible that dissolved iron could be present in flooded areas of the mine with limited oxygen (a low to negative oxidation reduction potential (ORP) was measured behind the 11th West and 17th West seals), but at the somewhat alkaline pH (7.1 to 7.6) of the mine water, this iron would most likely precipitate within minutes to hours of discharging into surface flow channels in an oxygen rich environment. Turbulent flow that causes entrainment of oxygen would increase the rate of oxidation.
- We concur that the majority of the iron in water draining through the accessible portions of the Mill Fork area will occur as fine colloidal particles. These particles may either flocculate together and move as a low-density gel or settle to the mine floor in low-flow areas.
- Iron precipitate material will accumulate in mine floor flow channels or sumps over time, most likely at locations with a low flow velocity. Therefore, we believe that iron precipitate accumulation at the French drain is likely. Because the drain pipe inlet is above the invert elevation of the plug, a small ponded area is required to direct inflow to the drain.

Long term drainage potential:

- Iron and sulfate concentrations in mine water draining from the 11th West and 17th West seals were presented along with depletion curves for each constituent extrapolated to a zero concentration. These depletion time estimates were prepared with data from just two years of monitoring, and may not represent the long term condition. The linear trend lines were poorly correlated with the data ($r^2 < 0.3$ for iron) and the conclusion that total iron would decrease to 0 mg/L by 2016 in the 11th West sump is considered improbable. With two years of data, natural variability or operationally-influenced fluctuations in the second year of monitoring could have been incorrectly inferred as a declining trend. It is possible that the mine drainage could contain iron at a low concentration for decades to centuries if sulfide minerals in previously dry portions of the mine become wet after closure (e.g., walls in flooded or humid areas).

- It is possible that the total load of iron in mine drainage may eventually decline over time if flow rates stabilize or decrease, and some depletion of the source minerals occurs. Reduced groundwater infiltration would mean less water is available to interact with exposed minerals and mobilize iron and consequently, preferential flow paths could form to direct water over weathered rather than fresh rock.
- The long term viability of the French drain and directional drill hole will depend on the release rate of iron from the mine workings and the settling rate of suspended iron particles in and around the drain. Unless the longwall panels that intersect sulfur-bearing rock are sealed off completely, it is difficult to control the release of iron, but it may be possible to control iron flocculation around the drain system, as described below.

The long term viability of the French drain collection system and directional drain hole relies on the prevention or minimization of physical clogging due to an accumulation of iron oxide precipitate material. It is possible that construction of shallow sediment retention berms inby the drain may improve the performance, longevity, and efficiency of the drain system by promoting sediment accumulation upstream of the drain. A series of berms could be constructed across the entries upstream of the plugs to slow the flow of water through the mine, and provide residence time for settling transported iron. If flow rates decline over time then it is possible that the retention berm system could become more efficient as the residence time in each small pool behind the berms would increase.

2.7 Mine Storage and Pipe Flow

Golder reviewed the mine volume estimates provided in the Final Closure Plan and found the estimated volumes to be reasonable. Golder's review utilized the two dimensional mine plans provided by the Owner; a three dimensional model has not been developed for the mine. The estimated volume for the longwall gob appears to use a void ratio of approximately 0.25; this value is near the lower end of the range in published literature. Increasing the estimated void space to the higher end of the range (0.4) increases the volume of the live storage by approximately 15% (to approximately 1,100 acre feet from approximately 960 acre feet). The porosity in the longwall gob will be effected by many variables including overburden thickness, strength, and bedding. Due to the significant depth of the workings, we believe that the estimated porosity is reasonable.

The primary drain pipe consists of approximately 4,850 feet of 10 inch (nominal) HDPE pipe at a grade of approximately 1%. The Final Closure Plan states that 1,000 gallons per minute (gpm) is the maximum anticipated flow. Our calculations estimate that the primary drain pipe can provide for flow in excess

1,000 gpm under no head. Flows above this will result in additional ponding at the primary plugs, and an increase of the driving head on the pipe which will increase the flow rate. At approximately 20 feet of driving head, we estimate the pipe capacity at approximately 1,500 gpm.

3.0 CONCLUSIONS AND RECOMMENDATIONS

Based on our review, the primary plug designs are suitable for the purpose in the short term. Although we consider it unlikely, especially in the short term, the secondary plug designs presents several concerns and could potentially result in failure if subjected to the maximum potential hydraulic loads. Long term effectiveness of the plug system is more difficult to assess and will be impacted by changing conditions in the mine. Changing conditions in the mine potentially include:

- Plugging of the primary spillway (French drain and directional drill hole) resulting in the maximum design heads on the primary plugs
- Roof falls or sloughing ribs which block drainage routes (either upstream or downstream of the plug system), and could potentially increase the hydraulic load on the plugs
- Changes in the water chemistry (potentially degrading concrete or rock)
- The hydraulic properties of the strata around the seal are likely to change due to movement of the strata (creep), weathering, and hydraulic pressure; over time, the surrounding rock mass will likely present the weakest element (MSHA 2015, Kirkwood and Wu 1995). Immersion testing indicated slightly, to non-sensitive material; however, this test may not fully represent the long term rock behavior of the strata.
- Long term degradation of the plug concrete (e.g., cracking due to changes in the stress regime) resulting in increased seepage
- Filling of the Rilda Canyon workings, and the potential development of springs

As noted in the MSHA review letter, assurance cannot be provided that the system will function as intended in perpetuity. Ponding water in the mine will present a long term potential for both catastrophic failure and development of new seeps/springs at the ground surface. Given the design, and assuming the plugs are constructed properly, we consider the likelihood of a failure of the plug system resulting in a catastrophic release to the ground surface to be very low, but the damages (costs, environmental impacts) of such a release would make this a high risk hazard. Although the information reviewed is insufficient to quantitatively assess the risk, we consider seepage to ground surface to be a much lower risk; the risk will increase with the filling of the Rilda Canyon workings and the ponding of water behind the 1st Right XC-37 Entry 3 and 4 Secondary Plugs.

Our review has identified several concerns with the Final Closure Plan as supplemented by the technical specifications. As previously detailed, recommendations to increase the longevity of the plugs and improve long term effectiveness to protect human health and the environment include:

- Full time construction quality assurance by a qualified third party.
- Require that significant effort be expended in preparing the plug locations. Site preparation is critical to effective plug construction.
- Require contact grouting be completed after concrete has cooled. Contact grouting will reduce seepage around the plug, increasing the Factor of Safety and longevity.

- Require a trial run prior to beginning the first concrete pour (as suggested in the RFP). A trial run will help reduce the potential for delivering and including poor quality (out of spec) concrete to the plug.
- Control the potential for thermal cracking by minimizing heat of hydration (by maximizing the use of fly-ash in the SCC mix, pouring the plugs slowly), insulating the plug faces, leaving forms in place until plugs have cooled, and allowing for slower strength gain (i.e., specify the minimum 56-day strength).
- Monitor the heat of hydration throughout the plugs to assess the potential for cracking.
- Although they are expected to last for many years, as with any infrastructure, a mine plug will have a finite life and requires monitoring and maintenance. We recommend maintaining long term access for inspection, monitoring, and maintenance. Regular inspection and monitoring will verify the performance of the seals over time (Kirkwood and Wu, 1995).
- Installing additional monitoring equipment downstream of the primary and secondary plugs to assess seepage around the plugs. If long term access is not maintained, remote monitoring can be utilized to help assess plug performance over time.
- Installing sediment traps inby the primary drain to reduce the flow velocity and allow iron precipitates to settle out away from the French drain, increasing the likelihood that the French drain and directional borehole remains open and functional.
- Installing trash screens upstream of the primary plug would prevent floating materials (i.e., miscellaneous mine refuse/debris) from reaching and potentially plugging the French drain system and monitoring holes. Construction materials should be selected for long term durability in the mine environment (e.g., geosynthetic mesh, fiberglass roof bolts).
- Removing or redesigning the 1st Right Secondary Plugs would allow for future access to the primary plugs for maintenance or monitoring. Additionally, it would reduce the potential for impounding water at high head with insufficient ground cover and barrier pillar thickness.

  Alternatively, concerns regarding minimum ground cover thickness could be addressed by carrying out hydraulic jacking tests at the plug location, or the plug could be redesigned to reduce the maximum head ponded by including a drain pipe.
- Development of a hydrogeologic model would allow for quantitative assessment of seepage under the various ponding scenarios (i.e., seepage around the plug, seepage to Crandall Canyon, and development of springs in North Rilda Canyon).
- Installing additional, long term roof support on both sides of the plug to reduce development of seepage paths through the strata (Harteis, S.P, D.R. Dolinar, and T.M Taylor, 2008).

As a result of the Gold King Mine release in 2015, a technical evaluation of the incident was prepared by a peer review by engineers at the USGS and US Army Corp of Engineers (USBR, 2015). The findings of this evaluation noted that while dams and tailings impoundments are subject to federal and state dam safety regulations, plugs in abandoned underground mines are not, but should be; a "flooded mine is in effect a dam, and failure must be prevented by routine monitoring, maintenance, and in some cases remediation."

4.0 CLOSING

This review has been performed in a manner consistent with that level of care and skill ordinarily exercised by other professionals currently practicing under similar conditions in the same locality, subject to the time limits and financial, physical or other constraints applicable to the services provided. No warranty, express or implied is made.

Should you need any additional clarification or have questions, please contact the undersigned.

Sincerely,

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